

On complex adaptive systems and terrorism

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Abstract

Complex adaptive systems (CAS) are ubiquitous in nature. They are basic in social sciences. An overview of CAS is given with emphasis on the occurrence of bad side effects to seemingly "wise" decisions. Hence application to terrorism is given. Some conclusions on how to deal with this phenomena are proposed.

1 Introduction

Terrorism is an important phenomena that deserves to be studied using all possible approaches. Here we use complex adaptive systems (CAS) [Boccaro 2004] to study it. We use some aspects of CAS and present some conclusions about terrorism. One of our main conclusions is that total eradication of terrorism is highly unlikely. It is more feasible to localize it. In sec. 2 CAS are reviewed. Terrorism is then defined. Then we apply CAS to terrorism using game theory with mistakes [Sato Crutchfield 2002, Ahmed et al 2003]. Some comments are given on the work of Galam et al [Galam 2003, Galam and Mauger 1996] who uses percolation theory [Aharony and Stauffer 1992] to study terrorism. In sec. 3 some general conclusions on CAS are presented then used to give several proposals on handling terrorism.

2 Complex adaptive systems and terrorism

Definition (1): A complex adaptive system consists of inhomogeneous, interacting adaptive agents.

Definition (2): An emergent property of a CAS is a property of the system as a whole which does not exist at the individual elements (agents) level.

Typical examples are the brain, the immune system [Matzinger 2002, Segel and Cohen 2001], the economy, social systems, ecology [Edelstein-Keshet 1988], insects swarm, etc

The existence of emergent properties implies that to understand a complex system one has to study the system as a whole and not to decompose it into its constituents. This totalistic approach is against the standard reductionist one, which tries to decompose any system to its constituents and hopes that by understanding the elements one can understand the whole system.

Why should we study complex adaptive systems?

Most of the real systems are CAS. Moreover they have intrinsic unpredictability which causes some "seemingly wise" decisions to have harmful side effects. Therefore we should try to understand CAS to try to minimize such side effects.

How to model a CAS?

The standard approaches are

1. Ordinary differential equations (ODE), difference equations and partial differential equations (PDE).
2. Cellular automata (CA) [Ilachinski 2001].
3. Evolutionary game theory [Hofbauer and Sigmund 1998].
4. Agent based models.
5. Networks [Watts and Strogatz 1998] etc..

Some of these approaches are included in [Boccaro 2004].

Application to terrorism:

First we define what we mean by terrorism:

Definition (3): Terrorism is the attack on unarmed civilians. It is obvious that terrorism is a CAS.

Recently [Sato and Crutchfield 2002] have studied the dynamics of learning in multi-agent systems, where the agents use reinforcement learning. Their work was extended to evolutionary game theory by [Ahmed et al 2003]. Here we apply Sato Crutchfield idea to spiteful replicator dynamics so we propose the following form

$$\frac{dx_i}{dt} = x_i \sum_{j=1}^n x_j (\Pi_{ij} - \Pi_{ji}) + \gamma_i x_i \sum_{j=1}^n x_j \ln \left(\frac{x_j}{x_i} \right), \quad (1)$$

where $\gamma_i, i = 1, 2, \dots, n$ are nonnegative constants measuring the average rate of mistakes done by the player adopting strategy i . An immediate result from Eq. (1) is that $x_i \neq 0, i = 1, 2, \dots, n$. This means that eradication of (even wrong) ideas is extremely hard and that it is more practical to contain them. An obvious example is the idea of Nazism which has been beaten militarily more than 50 years ago yet it has not been eradicated.

Another interesting idea proposed recently by Galam [Galam 2003] is to use percolation theory [Stauffer and Aharony 1992] to understand terrorism and propose strategies to fight it. Consider a matrix of passive sympathizers who are not involved into any acts of terror yet they share the terrorists' motives but not acts. Terrorism will then be like a percolating phenomena in this matrix. If fraction of support p exceeds a given threshold say $p > p_c$, then terror will propagate but if $p < p_c$, then it will be contained. The bright idea of Galam is in realizing that to contain terror one may either affect the connectivity of the passive supporters q which is extremely difficult or by reducing the dimension of the social space d which equals $2(\text{space}) + \text{number of motives (called flags)}$ which the passive sympathizers share with the terrorists. He proposed the formula

$$p_c = a [(q - 1)(d - 1)]^{-b}, a = 1.287, b = 0.616, \quad (2)$$

where $q = 16, d = 10$. We expect that $d = 6$ since there are four main flags which can be identified as: Occupation of two countries, feeling that

religion is being attacked and supporting some repressive states. This makes $p_c \approx 10\%$ which agrees with Galam estimates.

3 Conclusions

Before a decision (concerning a CAS) is made the following points should be taken into considerations:

- (i) CAS should be studied as a whole hence reductionist point of view may not be reliable in some cases.
- (ii) CAS are open with nonlinear local interactions hence:
 - (a) Long range prediction is highly unlikely [Strogatz 2000, Holmgren 1996].
 - (b) When studying a CAS take into consideration the effects of its perturbation on related systems. This is also relevant to the case of natural disasters where an earthquake at a city can cause a widespread power failure at other cities.
 - (c) Expect side effects to any "WISE" decision.
 - (d) Mathematical and computer models may be helpful in reducing such side effects.
- (iii) Optimization in CAS should be multi-objective and not single objective [Collette and Siarry 2003].
- (iv) CAS are very difficult to control. Interference at highly connected sites may be a useful approach [Dogoretsev and Mendez 2004]. The inter-linked nature of CAS elements complicates both the unpredictability and controllability problems. It also plays an important role in innovations spread.
- (v) Memory effects should not be neglected in CAS. Also memory games have been studied [Smale 1980, Ahmed and Hegazi 2000].

Now how can these ideas help in proposing strategies in the war against terror?

We propose the following:

1. Terrorism should be studied as a whole. Security solutions alone cannot be successful since it does not affect p_c . In fact excessive force may increase d . This agrees with many observations. Changing d is possible through combined political, economic and social in addition to security actions.
2. Total eradication of terror is almost impossible. Sato-Crutchfield game shows that every possible strategy will be used. Thus containment and not eradication is the feasible goal.
3. Memory effects should be taken into considerations hence do not expect quick solutions.
4. Target interference to affect terror networks may be more effective than an all out one.
5. Expect side effects and some failures.
6. CAS are open and distributed [Kaneko 1993] systems hence take into consideration the effect of a decision on related people.

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